

WHAT IS CLAIMED IS:

1 1. A method for maximum a posteriori (MAP) decoding of an input
2 information sequence based on a first information sequence received through a channel,
3 comprising:

4 iteratively generating a sequence of one or more decode results starting with an
5 initial decode result; and

6 outputting one of adjacent decode results as a decode of the input information
7 sequence if the adjacent decode results are within a compare threshold.

1 2. The method of claim 1, wherein the iteratively generating comprises:
2 a. generating the initial decode result as a first decode result;
3 b. generating a second decode result based on the first decode result and a model
4 of the channel;
5 c. comparing the first and second decode results;
6 d. replacing the first decode result with the second decode result; and
7 e. repeating b-d if the first and second decode results are not within the compare
8 threshold.

1 3. The method of claim 2, wherein the generating a second decode result
2 comprises searching for a second information sequence that maximizes a value of an
3 auxiliary function.

1 4. The method of claim 3, wherein the auxiliary function is based on the
2 expectation maximization (EM) algorithm.

1 5. The method of claim 4, wherein the model of the channel is a Hidden
2 Markov Model (HMM) having an initial state probability vector π and probability density
3 matrix (PDM) of $P(X, Y)$, where $X \in \mathbf{X}$, $Y \in \mathbf{Y}$ and elements of $P(X, Y)$,
4 $p_{ij}(X, Y) = \Pr(j, X, Y | i)$, are conditional probability density functions of an information
5 element X of the second information sequence that corresponds to a received element Y
6 of the first information sequence after the HMM transfers from a state i to a state j , the
7 auxiliary function being expressed as:

8 $Q(X_1^T, X_{1,p}^T) = \sum_z \Psi(z, X_{1,p}^T, Y_1^T) \log(\Psi(z, X_1^T, Y_1^T))$, where p is a number of
 9 iterations, $\Psi(z, X_1^T, Y_1^T) = \pi_{i_0} \prod_{t=1}^T p_{i_{t-1}, i_t}(X_t, Y_t)$, T is a number of information elements
 10 in a particular information sequence, z is a HMM state sequence i_0^T , π_{i_0} is the probability
 11 of an initial state i_0 , X_1^T is the second information sequence, $X_{1,p}^T$ is a second information
 12 sequence estimate corresponding to a p th iteration, and Y_1^T is the first information
 13 sequence.

1 6. The method of claim 5, wherein the auxiliary function is expanded to be:

2
$$Q(X_1^T, X_{1,p}^T) = \sum_{t=1}^T \sum_{i=1}^n \sum_{j=1}^n \gamma_{t,ij}(X_{1,p}^T) \log(p_{ij}(X_t, Y_t)) + C$$

3 where C does not depend on X_1^T and

4
$$\gamma_{t,ij}(X_{1,p}^T) = \alpha_i(X_{1,p}^{t-1}, Y_1^{t-1}) p_{ij}(X_{1,p}^T, Y_t) \beta_j(X_{t+1,p}^T, Y_{t+1}^T)$$

5 where $\alpha_i(X_{1,p}^t, Y_1^t)$ and $\beta_j(X_{t+1,p}^T, Y_{t+1}^T)$ are the elements of forward and backward
 6 probability vectors defined as

7
$$\alpha(X_1^t, Y_1^t) = \pi \prod_{i=1}^t P(X_i, Y_i), \text{ and } \beta(X_1^T, Y_1^T) = \prod_{j=t}^T P(X_j, Y_j) \mathbf{1}, \quad \pi \text{ is an}$$

8 initial probability vector, $\mathbf{1}$ is the column vector of ones.

1 7. The method of claim 6, wherein a source of an encoded sequence is a
 2 trellis code modulator (TCM), the TCM receiving a source information sequence I_1^T and
 3 outputting X_1^T as an encoded information sequence that is transmitted, the TCM defining
 4 $X_t = g_t(S_t, I_t)$ where X_t and I_t are the elements of X_1^T and I_1^T for each time t , respectively, S_t
 5 is a state of the TCM at t , and $g_t(\cdot)$ is a function relating X_t to I_t and S_t , the method
 6 comprising:

7 generating, for iteration $p+1$, a source information sequence estimate $I_{1,p+1}^T$ that
 8 corresponds to a sequence of TCM state transitions that has a longest cumulative distance
 9 $L(S_{t-1})$ at $t = 1$ or $L(S_0)$, wherein a distance for each of the TCM state transitions is
 10 defined by $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ for the TCM state transitions at each t for

11 $t = 1, \dots, T$ and the cumulative distance is the sum of $m(\hat{I}_t(S_t))$ for all t , $m(\hat{I}_t(S_t))$ being
 12 defined as

13
$$m(\hat{I}_t(S_t)) = \sum_{i=1}^{n_c} \sum_{j=1}^{n_c} \gamma_{t,ij} (I_{1,p}^T) \log p_{c,ij} (Y_t | X_t(S_t)), \text{ for each } t = 1, 2, \dots, T, \text{ where}$$

14 $X_t(S_t) = g_t(S_t, \hat{I}_t(S_t))$, n_c is a number of states in an HMM of the channel and
 15 $p_{c,ij}(Y_t | X_t(S_t))$ are channel conditional probability density functions of Y_t when $X_t(S_t)$ is
 16 transmitted by the TCM, $I_{1,p+1}^T$ being set to a sequence of \hat{I}_t for all t .

1 8. The method of claim 7, wherein for each $t = 1, 2, \dots, T$, the method
 2 comprises:

3 generating $m(\hat{I}_t(S_t))$ for each possible state transition of the TCM;
 4 selecting state trajectories that correspond to largest
 5 $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ for each state as survivor state trajectories; and
 6 selecting $\hat{I}_t(S_t)$ s that correspond to the selected state trajectories as $I_{t,p+1}(S_t)$.

1 9. The method of claim 8, further comprising:

2 a. assigning $L(S_T) = 0$ for all states at $t = T$;
 3 b. generating $m(\hat{I}_t(S_t))$ for all state transitions between states S_t and all possible
 4 states S_{t+1} ;
 5 c. selecting state transitions between the states S_t and S_{t+1} that have a largest
 6 $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ and $\hat{I}_{t+1}(S_{t+1})$ that correspond to the selected state
 7 transitions;
 8 d. updating the survivor state trajectories at states S_t by adding the selected state
 9 transitions to the corresponding survivor state trajectories at state S_{t+1} ;
 10 e. decrementing t by 1;
 11 f. repeating b-e until $t = 0$; and
 12 g. selecting all the $\hat{I}_t(S_t)$ that correspond to a survivor state trajectory that
 13 corresponding to a largest $L(S_t)$ at $t = 0$ as $I_{1,p+1}^T$.

1 10. The method of claim 6, wherein the channel is modeled as $P_c(Y | X) =$
 2 $P_c B_c(Y | X)$ where P_c is a channel state transition probability matrix and $B_c(Y | X)$ is a

3 diagonal matrix of state output probabilities, the method comprising for each $t = 1, 2, \dots$,
 4 T:

5 generating $\gamma_{t,i}(I_{1,p}^T) = \alpha_i(Y_1^t \mid I_{1,p}^t) \beta_i(Y_{t+1}^T \mid I_{t+1,p}^T)$;

6 selecting an $\hat{I}_t(S_t)$ that maximizes $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$, where

7 $m(\hat{I}_t(S_t))$ is defined as

8 $m(\hat{I}_t(S_t)) = \sum_{i=1}^{n_c} \gamma_{t,i}(I_{1,p}^T) \beta_j(Y_t \mid X_i(S_t))$, n_c being a number of states in an HMM of

9 the channel;

10 selecting state transitions between states S_t and S_{t+1} that corresponds to a largest
 11 $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$; and

12 forming survivor state trajectories by connecting selected state transitions.

1 11. The method of claim 10, further comprising:

2 selecting $\hat{I}_t(S_t)$ that corresponds to a survivor state trajectory at $t = 0$ that has the
 3 largest $L(S_t)$ as $I_{1,p+1}^T$ for each pth iteration;

4 comparing $I_{1,p}^T$ and $I_{1,p+1}^T$; and

5 outputting $I_{1,p+1}^T$ as the second decode result if $I_{1,p}^T$ and $I_{1,p+1}^T$ are within the
 6 compare threshold.

1 12. A maximum a posteriori (MAP) decoder that decodes a transmitted
 2 information sequence using a received information sequence received through a channel,
 3 comprising:

4 a memory; and

5 a controller coupled to the memory, the controller iteratively generating a
 6 sequence of one or more decode results starting with an initial decode result, and
 7 outputting one of adjacent decode results as a decode of the input information sequence if
 8 the adjacent decode results are within a compare threshold.

1 13. The decoder of claim 12, wherein the controller:

2 a. generates the initial decode result as a first decode result;

3 b. generates a second decode result based on the first decode result and a model
 4 of the channel;

5 c. compares the first and second decode results;

6 d. replaces the first decode result with the second decode result; and

7 e. repeats b-d until the first and second decode result are not within the compare

8 threshold.

1 14. The decoder of claim 13, wherein the controller searches for information

2 sequence that maximizes a value of an auxiliary function.

1 15. The decoder of claim 14, wherein the auxiliary function is based on

2 expectation maximization (EM).

1 16. The decoder of claim 15, wherein the model of the channel is a Hidden

2 Markov Model (HMM) having an initial state probability vector π and probability density

3 matrix (PDM) of $\mathbf{P}(X, Y)$, where $X \in \mathbf{X}$, $Y \in \mathbf{Y}$ and elements of $\mathbf{P}(X, Y)$,

4 $p_{ij}(X, Y) = \Pr(j, X, Y | i)$, are conditional probability density functions of an information

5 element X of the second information sequence that corresponds to a received element Y

6 of the first information sequence after the HMM transfers from a state i to a state j , the

7 auxiliary function being expressed as:

8
$$Q(X_1^T, X_{1,p}^T) = \sum_z \Psi(z, X_{1,p}^T, Y_1^T) \log(\Psi(z, X_1^T, Y_1^T)),$$
 where p is a number of

9 iterations, $\Psi(z, X_1^T, Y_1^T) = \pi_{i_0} \prod_{t=1}^T p_{i_{t-1}, i_t}(X_t, Y_t)$, T is a number of information elements

10 in a particular information sequence, z is a HMM state sequence i_0^T , π_{i_0} is the probability

11 of an initial state i_0 , X_1^T is the second information sequence, $X_{1,p}^T$ is a second information

12 sequence estimate corresponding to a p th iteration, and Y_1^T is the first information

13 sequence.

1 17. The decoder of claim 16, wherein the auxiliary function is expanded to be:

2
$$Q(X_1^T, X_{1,p}^T) = \sum_{t=1}^T \sum_{i=1}^n \sum_{j=1}^n \gamma_{t,ij}(X_{1,p}^T) \log(p_{ij}(X_t, Y_t)) + C$$

3 where C does not depend on X_1^T and

4
$$\gamma_{t,ij}(X_{1,p}^T) = \alpha_i(X_{1,p}^{t-1}, Y_1^{t-1}) p_{ij}(X_{t,p}, Y_t) \beta_j(X_{t+1,p}^T, Y_{t+1}^T)$$

5 where $\alpha_i(X_{1,p}^t, Y_1^T)$ and $\beta_j(X_{t+1,p}^T, Y_{t+1}^T)$ are the elements of forward and backward

6 probability vectors defined as

7 $\alpha(X_1^t, Y_1^t) = \pi \prod_{i=1}^t P(X_i, Y_i)$, and $\beta(X_{t+1}^T, Y_{t+1}^T) = \prod_{j=t+1}^T P(X_j, Y_j) \mathbf{1}$, π is an initial

8 probability vector, $\mathbf{1}$ is the column vector of ones.

1 18. The decoder of claim 17, wherein a source of an encoded sequence is a
 2 trellis code modulator (TCM), the TCM receiving a source information sequence I_1^T and
 3 outputting X_1^T as an encoded information sequence that is transmitted, the TCM defining
 4 $X_t = g_t(S_t, I_t)$ where X_t and I_t are the elements of X_1^T and I_1^T for each time t , respectively, S_t
 5 is a state of the TCM at t , and $g_t(\cdot)$ is a function relating X_t to I_t and S_t , the controller
 6 generates, for iteration $p+1$, an input information sequence estimate $I_{1,p+1}^T$ that
 7 corresponds to a sequence of TCM state transitions that has a longest cumulative distance
 8 $L(S_{t-1})$ at $t = 1$ or $L(S_0)$, wherein a distance for each of the TCM state transitions is
 9 defined by $L(S_{t+1}) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ for the TCM state transitions at each t for
 10 $t = 1, \dots, T$ and the cumulative distance is the sum of $m(\hat{I}_t(S_t))$ for all t , $m(\hat{I}_t(S_t))$ being
 11 defined as

12 $m(\hat{I}_t(S_t)) = \sum_{i=1}^{n_c} \sum_{j=1}^{n_c} \gamma_{t,ij} (I_{1,p}^T) \log p_{c,ij} (Y_t | X_t(S_t))$, for each $t = 1, 2, \dots, T$, where

13 $X_t(S_t) = g_t(S_t, \hat{I}_t(S_t))$, n_c is a number of states in an HMM of the channel and
 14 $p_{c,ij}(Y_t | X_t(S_t))$ are channel conditional probability density functions of Y_t when $X_t(S_t)$ is
 15 transmitted by the TCM, $I_{1,p+1}^T$ being set to a sequence of \hat{I}_t for all t .

1 19. The decoder of claim 18, wherein for each $t = 1, 2, \dots, T$, the controller
 2 generating $m(\hat{I}_t(S_t))$ for each possible state transition of the TCM, selecting state
 3 trajectories that correspond to largest $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ for each state as
 4 survivor state trajectories, and selecting $\hat{I}_{t+1}(S_{t+1})$ s that correspond to the selected state
 5 trajectories as $I_{t+1,p+1}(S_{t+1})$.

1 20. The decoder of claim 19, wherein the controller:
 2 a. assigns $L(S_T) = 0$ for all states at $t = T$;
 3 b. generates $m(\hat{I}_t(S_t))$ for all state transitions between states S_t and all possible
 4 states S_{t+1} ;

5 c. selects state transitions between the states S_t and S_{t+1} that have a largest
 6 $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ and $\hat{I}_{t+1}(S_{t+1})$ that correspond to the selected state
 7 transitions;

8 d. updates the survivor state trajectories at states S_t by adding the selected state
 9 transitions to the corresponding survivor state trajectories at state S_{t+1} ;

10 e. decrements t by 1;

11 f. repeats b-e until $t = 0$; and

12 g. selects all the $\hat{I}_t(S_t)$ that correspond to a survivor state trajectory that
 13 corresponding to a largest $L(S_t)$ at $t = 0$ as $I_{1,p+1}^T$.

1 21. The decoder of claim 20, wherein the channel is modeled as $\mathbf{P}_c(Y | X) =$
 2 $\mathbf{P}_c \mathbf{B}_c(Y | X)$ where \mathbf{P}_c is a channel state transition probability matrix and $\mathbf{B}_c(Y | X)$ is a
 3 diagonal matrix of state output probabilities, for each $t = 1, 2, \dots, T$, the controller:

4 generates $\gamma_{t,i}(I_{1,p}^T) = \alpha_i(Y_t^t | I_{1,p}^t) \beta_i(Y_{t+1}^T | I_{t+1,p}^T)$;

5 selects an $\hat{I}_t(S_t)$ that maximizes $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$, where $m(\hat{I}_t(S_t))$
 6 is defined as

7 $m(\hat{I}_t(S_t)) = \sum_{i=1}^{n_c} \gamma_{t,i}(I_{1,p}^T) \beta_j(Y_t | X_t(S_t))$, n_c being a number of states in an HMM of
 8 the channel;

9 selects state transitions between states S_t and S_{t+1} that corresponds to a largest
 10 $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$; and

11 forms survivor state trajectories by connecting selected state transitions.

1 22. The decoder of claim 21, wherein the controller selects $\hat{I}_t(S_t)$ that
 2 corresponds to a survivor state trajectory at $t = 0$ that has the largest $L(S_t)$ as $I_{1,p+1}^T$ for each
 3 pth iteration, compares $I_{1,p}^T$ and $I_{1,p+1}^T$, and outputs $I_{1,p+1}^T$ as the second decode result if $I_{1,p}^T$
 4 and $I_{1,p+1}^T$ are within the compare threshold.